Evaluation of the NCEP Regional Reanalyses over Complex Terrain
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Introduction

This study is aimed at contributing to meet the GAPP goal to develop and demonstrate a capability to make reliable monthly to seasonal predictions of precipitation and land-surface hydrologic variables through improved understanding and representation of land surface and related hydrometeorological and boundary layer processes in climate prediction models. Our efforts are directed to the GAPP Science Question: what is the role of hydrologic prediction in coupled land atmosphere modeling? Specifically, this research is encapsulated in the synthesis product: *Provide a regional reanalysis of the atmospheric and land surface states using state-of-the-science numerical modeling and data assimilation systems*.

The two main objectives of this project are: (1) to evaluate how well the North American Regional Reanalyses (NARR) capture the morphology of major winter storms and (2) to downscale the NARR to a high resolution grid spacing. Progress towards these two objectives during the first year of this project are summarized below. Adjustment and refinement of project plans for year 2 are presented for each objective as well.

Evaluation of the North American Regional Reanalyses

M.S. graduate student Greg West and co-PI Jim Steenburgh have been evaluating characteristics of the North American Regional Reanalyses (NARR). Their preliminary results entitled: "Anomalous Pressure and Height Changes in the North American Regional Reanalyses" were presented at the North American Regional Reanalysis Users Workshop at the AMS Annual Meeting and an article is in preparation for submission to the *Bulletin of the American Meteorological Society*. While developing a climatology of Intermountain cyclones that are often associated with major winter storms and widespread precipitation, they discovered two types of anomalous pressure and height analyses in the NARR. The first is anomalously high or low pressures characterized by bull's-eyes in mean sea level pressure (MSLP) analyses. The second is physically unrealistic MSLP fluctuations of 6hPa or more between 3h analysis times. Both are accompanied by changes in geopotential heights aloft.

The bull's-eyes appear to be a result of bad or missing data being incorporated into the analysis. These large bull's-eye anomalies occurred approximately 6 times in the year examined. In the fluctuation cases (see Figure 1) some of the anomalies could result from the way in which surface pressure is assimilated. Surface pressure observations used in producing the NARR were obtained from two sources: the Meteorological Data Lab for all times, while additional data from the NCEP/NCAR Global Reanalysis data set are incorporated only at synoptic times. These types of anomalies occurred about 15 times in the year examined. The anomalous changes brought to light by this study have implications for others using the NARR. However, it should be noted that these anomalous changes affect only a limited area of the domain and at a limited number of time steps. EMC staff are collaborating with us to assess the causes for these analysis characteristics.

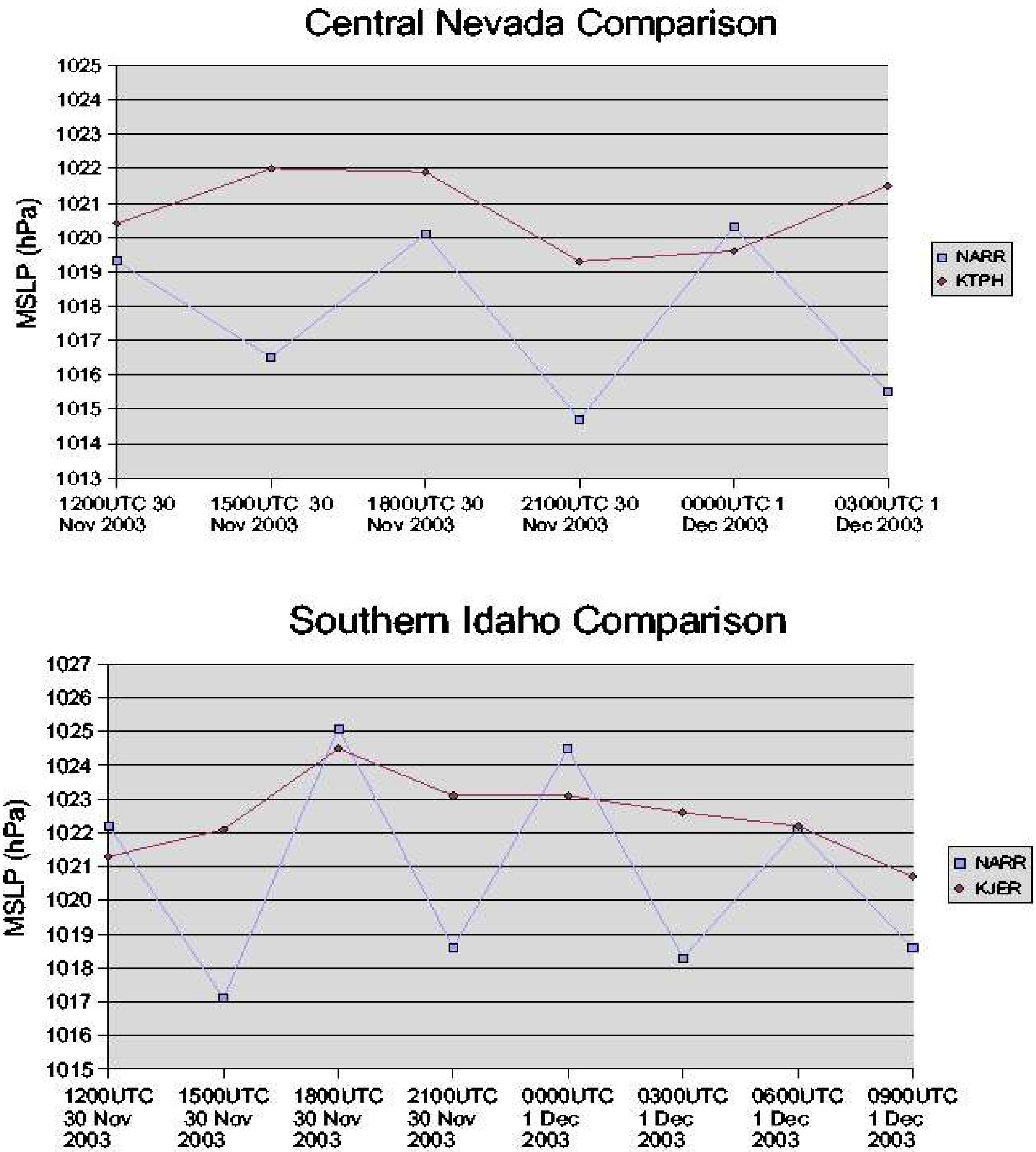

Figure 1. Comparison of mean sea level pressure from the NARR and from a) Tonopah (KTPH) in central Nevada and b) Jerome (KJER) in southern Idaho.

PhD. graduate student Jason Shafer has downloaded the 700 mb temperature fields for the entire NARR period of record (1979-2003) in order to assess both the quality of the NARR as well as objectively evaluate the occurrence of strong fronts over the West. Derived quantities, such as strong mid-tropospheric temperature gradients, provide a means to test the suitability of the NARR for a wide variety of applications.

During FY05, we will emphasize evaluation of the performance of the NARR during specific cases of heavy precipitation throughout the West. In addition to the 1996-97 storm cycle that was discussed in the original proposal, we will also evaluate regional analyses obtained from the R-CDAS version of the NARR for the heavy precipitation event throughout the southern tier of Western states during January 2005. Extensive verification assets during this period make evaluation of the characteristics of the NARR and R-CDAS more straightforward than for earlier periods. Based upon the information presented by the EMC NARR project team at the NARR Workshop, some of the research plans for FY05 will be modified. For example, it will not be possible to evaluate differences resulting from the different states of soil moisture during the overlapping analysis periods as only the analyses from the end of each production cycle have been archived. In addition, access to the analyses on the model's native grid is not possible.

Downscaling the NARR

PhD. graduate student David Myrick and co-PIs John Horel and Steven Lazarus have been investigating methods to downscale coarse resolution analyses to high resolution surface grids. A paper describing some of this work entitled "Local adjustment of the background error correlation for surface analyses over complex terrain" is in press and will be published in *Weather and Forecasting.* The accompanying figure (Fig. 7 from the paper) demonstrates the sensitivity of the analysis to selected methodology choices. The terrain between gridpoints is used to modify locally the background error correlation matrix. This modification helps to reduce the influence across mountain barriers of corrections to the background field that are derived from surface observations. This change to the background error correlation matrix was tested using an analytic case of surface temperature that encapsulates the significant features of nocturnal radiation inversions in mountain basins, which can be difficult to analyze because of locally sharp gradients in temperature. Adding the intervening terrain term led to solutions that match more closely the specified analytic solution. The intervening terrain term was further evaluated in objective analyses over the western United States. Local adjustment of the background error correlation matrix led to improved surface temperature analyses by limiting the influence of observations in mountain valleys that may differ from the weather conditions present in adjacent valleys.

PI John Horel has been involved with efforts of the NWS Office of Science and Technology to develop a high resolution (order 5 km) analysis of record that could eventually provide retrospectively a mesoscale version of the NARR. See http://www.met.utah.edu/jhorel/homepages/jhorel/mac.htm for further details.

PIs Will Cheng and Jim Steenburgh have been evaluating the WRF model in order to lead to future improvements in its data assimilation and modeling system. A paper entitled "Evaluation of Surface Sensible Weather Forecasts by the WRF and ETA Models over the Western United States" has been submitted to *Weather and Forecasting*. This evaluation of the surface sensible weather forecasts uses high density observations provided by the MesoWest cooperative networks and illustrates the performance characteristics of the Cooperative Institute for Regional Prediction (CIRP) Weather Research and Forecast (WRF) and Eta models over the western United States during the 2003 warm season. In general, the CIRP WRF produced larger 2-m temperature and dewpoint mean absolute and bias errors (MAE and BE, respectively) than Eta. The CIRP WRF overpredicted the 10-m wind speed, whereas the Eta exhibited an underprediction with a comparable error magnitude to WRF. Tests using the Oregon State University (OSU) land surface model (LSM) in the CIRP WRF, instead of a simpler slab soil model, suggest that using a more sophisticated LSM offers no overall advantage in reducing WRF BEs and MAEs for the aforementioned surface variables. Improvements in the initialization of soil temperature in the slab soil model, however, did reduce the temperature bias in the CIRP WRF. These results suggest that improvements in LSM initialization may be as or more important than improvements in LSM physics. The results of this study suggest that a concerted effort must be undertaken to improve both the LSM initialization and parameterization of coupled land surface/boundary layer processes to produce more accurate surface sensible weather forecasts.

During FY05, coordination with EMC staff will continue in order to test the 2DVAR version of their EDAS and WRF data assimilation systems. The goal of this evaluation is to assess to what extent the 2DVAR approach can be used to downscale the operational RUC and eventually lead to downscaling the NARR.

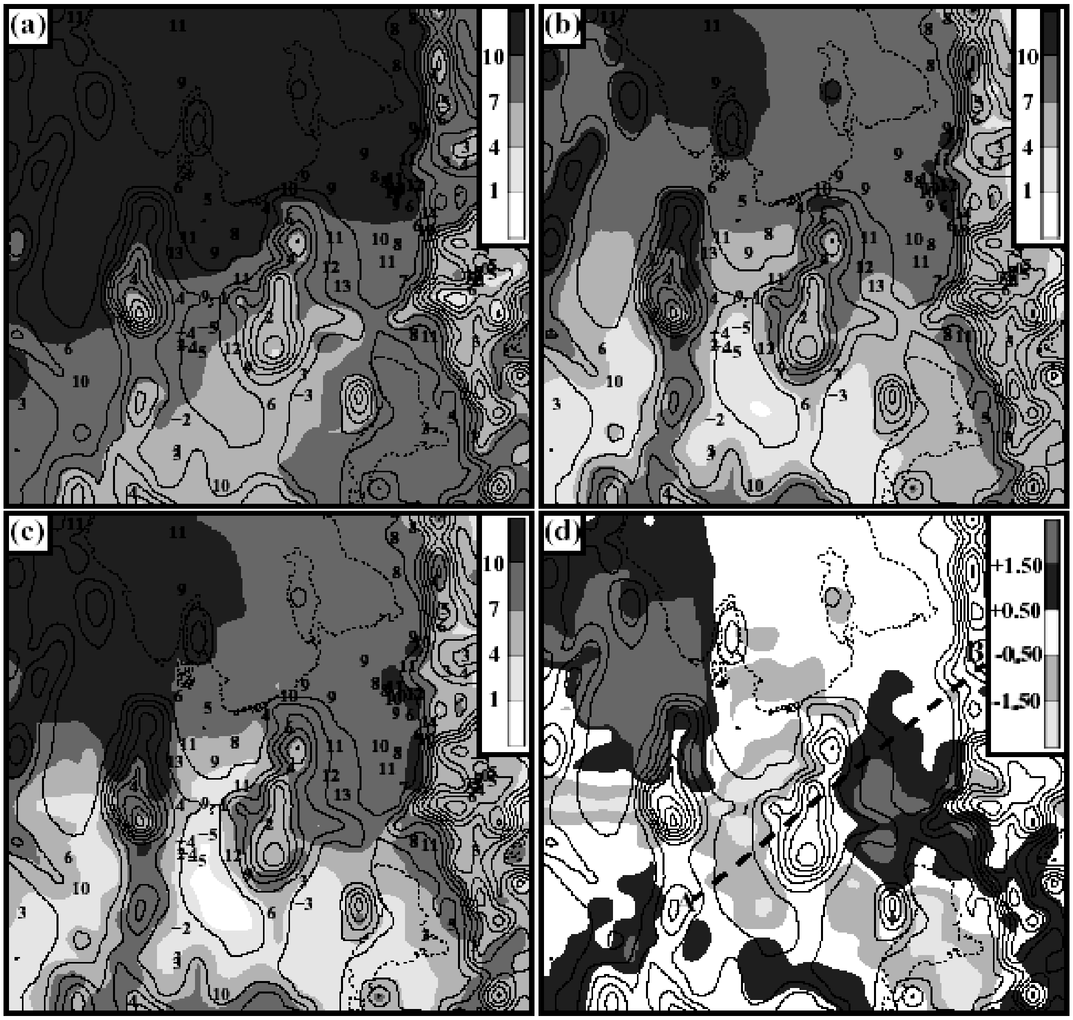

Figure 7: Wasatch Front region surface temperature observations (°C) and (a) RUC, (b) ADAS and (c) ADAS with ITT analyses of temperature (°C) for 1300 UTC 10 April 2003. (d) Difference between ADAS analyses with and without ITT (panel c minus panel b). Terrain and lakes are denoted by solid and dashed lines, respectively. The surface cross section shown later in Fig. 8 is denoted by dashed line AB in (d).